Self-Assembled 2D Protein Crystals as Templates for Creating Ordered Metallic Nano-Arrays

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The arrangement of inorganic materials into nanoscale ordered arrays holds great promise for the production of new types of electronic, magnetic, and photonic devices. Fabricating ordered arrays on the nanoscale exceeds the limits of traditional lithographic techniques; therefore, new techniques, including those involving biomolecules such as proteins, are under investigation.

Genetically engineered proteins have been assembled to act as templates to create nano arrays of semiconducting and metallic materials. Initially we being by isolating a protein from *Sulfolobus shibatae*, a bacterium that lives in geothermal hot-spring. This protein is genetically modified to create a chemically active site on its edge, and is next cloned into a harmless form of *Escherichia coli* bacteria, which can be grown easily in vats. Heating the resulting bacterial stew destroys the *E.Coli* proteins, allowing us to isolate large amounts of the heat-tolerant *Sulfolobus* protein.

The purified protein naturally forms ring-shaped structures varying in size from ten to twenty nanometers across, called chaperonins. The chaperonins are next applied to substrates such as silicon wafers, where they self-assembled into large, hexagonal, periodic patterns. A slurry of nanoparticles of gold or a semiconducting material called cadmium selenide-zinc sulphide is added and adheres only to active sites around the “hole” in each protein ring. The resulting precise, regular arrays of nanoparticles closely resemble similar patterns used in the microelectronics industry — only much smaller. Such arrays of nanoparticles could have future applications such as in computer memories, sensors or logic devices.

Conventional TEM imaging and high resolution nanoscale imaging and characterization was conducted on a FEI Tecnai F20 operating at 200 kV. Images were recorded using STEM HAADF imaging mode, while elemental characterization of all samples was confirmed using X-ray Energy Dispersive and Electron Energy Loss Spectroscopy. Control experiments conducted without exposure to the metal salts resulted in 2D crystals without ordered metallic arrays.

We observed that the Nanogold particles covalently bound to the chaperonin template were hexagonally packed and aggregated in the cores of the chaperonins (Fig. 2). In contrast, the electroless deposition resulted in a non-uniform distribution of nickel on the chaperonin surface with regions of high density that yield the hexagonally packed array (Fig. 3).

These results demonstrate that genetically modified chaperonins can direct the formation and ordering of inorganic arrays of preformed metal particles or their precursors.

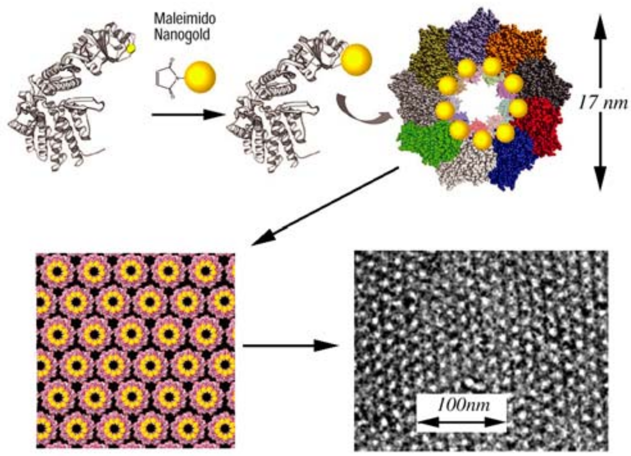

Fig.1.Model depicting the assembly of genetically engineered Chaperonins self-assemble into ordered arrays having covalently attached 1.4nm NanoGold.

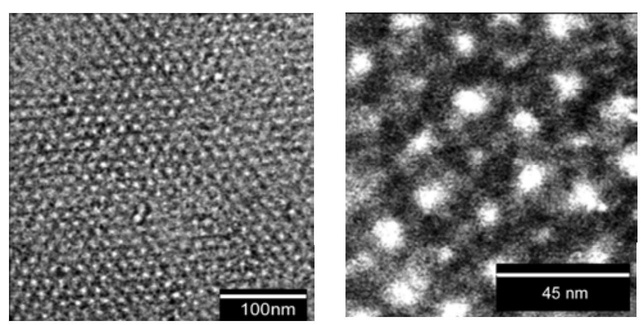

Fig. 2. Nanoscale ordered Au particles on *S. shibatae* chaperonin protein template

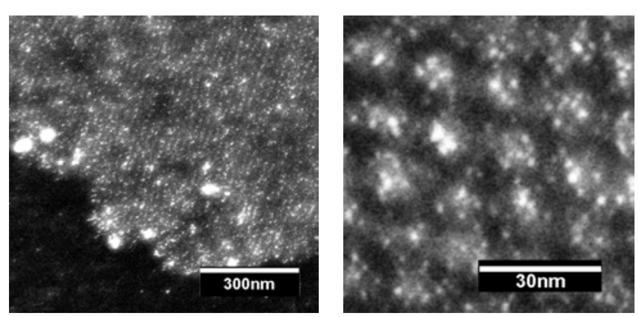

Fig. 3. Nanoscale ordered Ni particles on engineered *S. shibatae* chaperonin protein template

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